1. (a) Plot and explain the temperature dependence of conductivity for Al and Ge.(5%)
   (b) Give your estimation of conductivity for Al and Ge at 25 ℃.(5%)
   (c) Explain the difference of conductivity between Al and Ge at 25 ℃.(5%)

2. For a hypothetical simple cubic crystal with lattice parameter a., the atomic displacements could be described by harmonic waves. Furthermore, the relationship between frequency ω and wave number k is given by

$$\omega = 2\iota^{1/2} \left| \sin(ka/2) \right|$$

where ι is related to the atomic displacements

(a) What is the group velocity Vg for these waves ? (5%)
(b) What are the wavenumber values for which Vg=0 ? (5%)
(c) What is the small k limit of Vg ? (5%)

3. In an X-ray diffraction experiment, the spread in wavelengths, or energy, in the incident beam will result in a broading of the diffraction peak.
   (a) Derive an expression for the width $\Delta(2\theta)$ in a diffraction peak which results from a spread in X-ray energy ΔE in the incident radiation.(10%)
   (b) What is the difference in angles (in degress) for the two peaks caused by the two $Cu_{k\alpha}$ lines ? (5%)
   Use the following information

Radiation	Energy(kev)
$k\alpha_1$	8.049
$k\alpha_2$	8.029

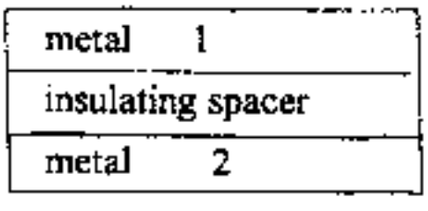
[Hint: $\lambda = hc/E$, $\ln\lambda = \ln(hc) - \ln E$]

4 (a) Why would you expect the effective mass of an electron at the bottom of the conduction band to be smaller than the effective mass of a hole at the top of the valence band ? (5%)

(b) From band theory we can divide materials into metals, semiconductors and insulators. Discuss how this is done.(5%)

5 The structure of a tunneling junction is shown below
Describe the requirements for the insulating spacer and metals if the spins of electrons need to be conserved, when the electrons pass through the tunneling junction. (10%)

(Hint: consider the thickness and energy band)



6. Consider N free electrons in a two-dimensional box of length L on each side.

(a) Apply periodic boundary conditions and find the K-space area per allowed point.(10%)

(b) What is the Fermi energy for this case?(5%)

7. In a free electron Fermi gas how can electrons participate in electrical conduction while not contributing to the heat capacity?(10%)

8. The electron configurations for Fe^{2+} and Cr^{3+} are $3d^6$ and $3d^3$, respectively. Write down the orbital angular momentum L, the spin angular momentum S, and the total angular momentum J for Fe^{2+} and Cr^{3+}.(10%)